

PATENT APPLICATION PAPERS

OF

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FOR: HIGH SENSITIVITY PRESSURE SWITCH

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## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention provides an improved circuit for use in use respirator type apparatus wherein the operating point of the apparatus is stabilized over large temperature ranges.

### 2. Description of the Prior Art

Apparatus for supplying oxygen to a patient in response to the patient's breathing cycles have been available in the prior art. In such devices, the breathing cycles are sensed by a capacitive pressure sensor, or transducer, which provides an electrical output signal corresponding to the breathing cycle. An example of such an apparatus is shown in U.S. Patent No. 4,612,928 to Tiep et al and U.S. Patent No. 5,134,886 to the inventor of the present invention. Capacitive transducers however are difficult to manufacture and tend to be hand fabricated, increasing the costs associated therewith. In addition, capacitive transducers tend to drift and fail over time.

In order to overcome the disadvantages of capacitive transducers, efforts have been made to use piezoresistive sensors as a replacement since they are readily available, inexpensive and reliable. In this case, a conventional differential amplifier provides a constant DC voltage output in response to a constant pressure input from the transducer. The amplifier typically has a voltage gain of 7000 or greater in order to detect a momentary nasal inspiration pressure of approximately .002 psi. However, it is difficult to maintain the stability of the pressure sensor at this high voltage gain over a large

temperature range. Although the sensors can be individually temperature compensated through testing, it is not practical for low cost production requirements.

sub'at What is desired is to provide an improved circuit for use in respirator type apparatus wherein a piezoresistive transducer is utilized to sense patient breaths or wherein temperature effects on circuit stabilization are minimized.

### SUMMARY OF THE INVENTION

The present invention provides a high sensitivity circuit for use in respiration type apparatus using a piezoresistive transducer and wherein the temperature effects on system stabilization are minimized. In addition, means are provided to reduce system initialization times. The apparatus can be designed to regulate the patient intake of oxygen or medicines, such as insulin and respiratory medicines.

The circuit comprises a differential sensor amplifier which responds to the output of the piezoresistive transducer, a dc negative feedback circuit connected to the output of the differential amplifier, means for reducing the initialization time of the circuit, circuit means for clamping the voltage output and a voltage comparator for tracking the circuit operating point and switching its output state when a sudden voltage change caused by a patient breath is detected.

The present invention thus provides a simple, reliable and inexpensive circuit for stabilizing the temperature effects in a respiration type apparatus using a piezoresistive transducer.

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Figure 2 is the schematic diagram for the block diagram shown in Figure 1.

The output of piezoresistive pressure sensor, or transducer, 10 is applied to the positive input of differential amplifier circuit 12 comprising differential amplifiers 44 and 46, the output voltage at node 48 being designed to be approximately 1.5 volts at system power-up. The voltage output at node 48 is coupled to DC negative feedback circuit 14 via initialization circuit 16 and the delay circuit comprising resistor 71 and capacitor 72. Circuit 16 comprises momentary relay contacts KIA and KIB (solid state switch can be used) and monostable multivibrator 50, the contacts KIA and KIB being closed when one-shot 50 is triggered – this occurs for approximately one second upon system power up. At this time, initialization circuit 16 shorts out 20 megohm resistor causing capacitor 72 charges rapidly to the circuit operating point (approximately 1.5 volts). When KIA is closed, the voltage at output node 48 is coupled to the positive input of negative feedback amplifier 52, the output of which is coupled to pressure sensor 10 and one input of differential amplifier 46, resulting in a negative voltage change at node 48. During this one second time period, the overall system gain is essentially zero. When KIA opens after the one second time period, the voltages in the circuit are balanced at the proper levels, in this case 1.5 volts. However, a long delay in the feedback is in effect and the AC gain is maximum. Since temperature drift occurs over periods of minutes, DC compensation is fast enough to take place. Gain at very low frequencies (breath rates) is very high; the result is essentially a zero gain at DC (1.5 volts) but a large AC gain at 1 hz and above (1.5 volt input increases slightly) due to the delay circuit. The AC gain occurs when a patient takes a breath.

Voltage clamp 18 comprises a diode clamp circuit 56 and voltage follower 58. The voltage clamp prevents large voltage excursions (operating range of the piezoresistive sensor circuit 10 is preferably maintained between 0.8 volts and 2.2 volts) at the sensor output due to breath expiration and 20 p.s.i. to approximately 50 p.s.i. pressure from oxygen (or medicine) released by the apparatus valve. Voltage clamping allows the circuit to recover rapidly so that approximately 20 breaths per minute can be sensed, preventing breaths from being missed or skipped.

Voltage comparator 20 comprises operational amplifier 60, the output on lead 22 being coupled to the apparatus valve control (not shown). The input to the negative terminal of amplifier 60 is not delayed during this one second power on mode; at this time, the input to the positive terminal of amplifier 60 is delayed by resistor 64 and capacitor 66. The delayed input is set to 0.1 volts below the reference (1.5 volts) by a divider comprising resistors 69 and 70. When the patient takes a breath (after the one second delay), a breath signal is detected by piezoresistive transducer 10 and coupled to the positive input of amplifier 60 (the voltage change at the negative input of amplifier 60 has essentially no effect due to 10 megohm resistor 64). This voltage change is detected and the output on lead 22 changes state because the reference signal at the negative terminal is essentially unchanged due to the delay provided by resistor 64. Amplifier 60 is initialized, as with the sensor amplifier, through relay contacts KIB upon power up. In essence, the voltage at the negative input of amplifier 60 after warm-up is 1.5 volts, the reference voltage. The voltage at the positive input of amplifier 60 is 1.4 volts with no breath being detected. When a breath (inspiration) is detected, the voltage at node 48 is increased to 1.6 volts or greater, this voltage being coupled to the positive input of

amplifier 60. At this time (trip point), amplifier 60 generates an output pulse of short duration on lead 22, the leading edge of the output pulse (3 volt amplitude) corresponding to the breath detection signal. This signal is coupled to the valve control causing gas to be dispensed to the pulmonary tract of the patient.

The present invention thus provides a simple, inexpensive and easily implemented improvement to respirator apparatus which minimizes sensor temperature sensitivity and increases system initialization times while providing high sensitivity.

While the invention has been described with reference to its preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its essential teachings.